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(54) Advanced polymer/wood composite structural member.

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(57) Polymer and wood composite structural members are manufactured by extruding and injection moulding a composition comprising polyvinyl chloride, wood fibre and optionally a concentration of an intentionally added waste stream. Such structural members have strength, workability, fast n r retention, resistance to rot and insect attack, and thermal properties sufficient to constitute an advanced composite wood replacement material. The advanced structural member can be used as a component in construction of any structure requiring sized lumber or specifically shaped wood products. In such an application, the structural members can be extruded in the shape of commonly available lumber. The structural members of the invention can also be extruded in complex shapes adapted to the assembly of windows and doors used in both residential and commercial structures. The structural members have a modulus, a coefficient of thermal expansion, a coefficient of elasticity, a compressive strength and other related properties ideal for use as a replacement for either metal or wood, window or door structural components. The preferred structural member is manufactured from a polyvinyl chloride and wood fibre composite that optionally contains an intentionally recycled impurity component. Such components comprise waste materials common in the manufacture of wood doors and windows. The cooperation between the amount of polymer material, the amount of an oriented wood fibre, and control over water content results in improved structural properties.

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The invention relates to polymer/wood composite materials, which can be used for th fabrication of structural members such as might be used in architectural applications, for example for residential and commercial applications, especially in the manufacture of windows and doors. More particularly, the invention relates to a structural member that can be used as a direct replacement for wood and metal components and having superior properties. The structural member of the invention can comprise sized lumber replacements and structural components with complex functional shapes such as wood and door rails, jambs, stiles, sills, tracks, stop sash and trim elements such as grid cove, bead, quarter round, etc.

Conventional window and door manufacture utilize structural members made commonly from hard and soft wood members and metal components, typically aluminum. Residential windows and doors are often manufactured from a number of specially shaped milled wood products that are assembled with glass sheets to form typically double hung or casement windows and sliding or hinged door units. Wood windows and doors while structurally sound and well adapted for use in many residential installations, require painting and other routine maintenance and can have problems under certain circumstances caused by the insect attack and by other deterioration of wood components. Wooden windows also suffer from cost problems related to the availability of suitable wood for construction. Clear wood and related wood products are slowly becoming scarce and costs increase rapidly as demand increases.

Metal windows and doors have been introduced into the marketplace. Such metal windows and doors are often made from extruded aluminum parts that when combined with rubber and thermoplastic curable sealant form utility components. Metal windows typically suffer from the drawback that they tend to be energy inefficient and tend to transfer substantial quantities of heat from a heated exterior to a cold environment.

Extruded thermoplastic materials have been used in the manufacture of window and door components. Typically, seals, edging, grill and coatings have been manufactured from filled and unfilled thermoplastic materials. Further, thermoplastic polyvinyl chloride materials have been combined with wooden structural members in the manufacture of windows by Andersen Corporation for many years, under the trade mark PERMA-SHIELD. The technology for forming such windows is disclosed in US-2926729 and US-3432883, and involves extruding a polyvinyl chloride envelope or coating around the wooden member as it passes through an extrusion dye. Such coated members are commonly used as structural components in forming the window fram or double hung or casement units.

Polyvinyl chloride thermoplastic materials have also been combined with wood products to make extruded materials. Prior efforts have failed to manufacture a material that can be directly extruded to form a structural member that is a direct replacement for wooden members. Such prior art composite members fail to have sufficient modulus (typically about 5 x 10^5 psi (3400 MPa) or greater), compressive strength, coefficient of thermal expansion, coefficient of elasticity, resistance to insect attack and rot or deterioration, combined with eas of working and fastener retention to be a direct wood replacement material. Further, many prior art extruded composites require post-extrusion milling to obtain a final useful shape. One class of composite, a polyvinyl chloride wood flour material, poses the added problem that wood dust tends to be explosive, as well as the need to size the wood particle, at certain concentrations of wood, dust or flour in the air.

Accordingly, a substantial need exists for the development of a composite material that can be directly formed by extrusion corresponding shape in a wood structural member. The need requires a modulus (stiffness), an acceptable coefficient of thermal expansion and an easily formable able material that can maintain reproducible stable dimensions, a material having low thermal transmission, improved resistance to insect attack and rot while in use and a material that can be cut, milled, drilled and fastened at least as well as wooden members.

A further need had existed in the art for many years with respect to the byproduct streams produced during the conventional manufacture of wooden windows and doors. Such window and door manufacturers have become significantly sensitive to the production of byproduct streams comprising substantial quantities of wood trim pieces, sawdust, wood milling by-products; recycled thermoplastic including recycled polyvinyl chloride and other byproduct streams. Commonly, these materials are burned for their heat value and electrical power generation or are shipped to qualified landfill sites for disposable. Such byproduct streams are contaminated with substantial proportions of hot melt and solvent-based adhesives, thermoplastic materials such a polyvinyl chloride, paint preservatives and other organic materials. A substantial need exists to find a productive, environmentally compatible use for such byproduct streams to avoid returning the material into the environment in an environmentally harmful way.

We have found that superior structural memb rs replacing conventional wooden and clad wooden structural members can compris a polyvinyl chloride and wood fibre composite mat rial containing a controlled amount of water and optionally an intentionally recycled proportion of window and door manufacture byproduct stream. The structural members of the inv ntion can be used in low strength applications ne ding a modulus of about 3 x 10^5 to 5 x 10^5 psi (2060 to 3440 MPa). Materials have also been produced that can be used in

medium strength applications needing a modulus of about 5×10^5 to 1×10^6 psi (3440 to 6900 MPa). Furth r, we have made materials that can survive the high strength requirements of window and door manufacture that ranges from 1×10^6 to 2×10^6 psi (6900 to 13800 MPa) and greater. Such streams can be contaminated with substantial proportions of hot melt adhesive, paints, solvent-based adhesive components, preservatives, polyvinyl chloride recycle, pigment, plasticizers, etc. We have found that the physical properties of the structural materials are not significantly lessened by the presence of such recycle. The structural member composites of this invention can achieve a high modulus, high compressive strength, reproducible dimensions, an acceptable coefficient of elasticity, and thermal expansion. We have found that the successful manufacture and physical properties of the polyvinyl chloride/ wood fibre composite requires intimate mixing and intimate contact between the polymeric material and the fibre. During the mixing of the polymer with wood fibre, the product attains control over moisture content, fibre alignment and materials proportions that achieves the manufacture of the superior wood replacement composite.

The term "structural member", for the purposes of this application, means a linear member with a regular cross-section or complex cross-section. Linear members can have a circular or oval cross-section and can have a triangular, rectangular, square, pentagonal, hexagonal, octagonal, etc., cross-section. Further, the cross-sectional shape can be adapted to the use of the linear member as a direct replacement for milled wood members in the manufacture of windows and doors. As such, the structural member typically has a length greater than either width or depth. The length can be typically greater than 30 cm (12 inches) and can often be as long as 16 feet. The structural members can come in regular lengths of 1, 1.3, 1.7, 2, 2.3, 3.3, 4, 5.3 m and so on (3, 4, 5, 6, 8, 10, 12, 16 etc., feet). Regular finished lumber dimensions can be used for manufacture of the structural members, finished 1x1, 1x2, 2x2, 2x4, 2x6, 2x10 members can be achieved.

PVC homopolymer, copolymer and polymer mixtures

Polyvinyl chloride is a common commodity thermoplastic polymer. Vinyl chloride monomer is made from a variety of different processes involving the reaction of acetylene and hydrogen chloride and the direct chlorination of ethylene. Polyvinyl chloride is typically manufactured by the free radical polymerization of vinyl chloride resulting. After polymerization, polyvinyl chloride is commonly combined with thermal stabilizers, lubricants, plasticizers, organic and inorganic pigments, fillers, biocides, processing aids, flame retardants or other commonly available additive materials, when needed. Polyvinyl chloride can also be combined with other vinyl monomers in the manufacture of polyvinyl chloride copolymers. Such copolymers can be linear copolym rs, can be graft copolymers, random copolymers, regular repeating copolymers, block copolymers, etc. Monomers that can be combined with vinyl chloride to form vinyl chloride copolymers include acrylonitrile; alpha-olefins such as ethylene, propylene, etc.; chlorinated monomers such as vinylidene, dichloride; acrylate monomers such as acrylic acid, methylacrylate, methylmethacrylate, acrylamide, hydroxyethyl acrylate, and others; styrenic monomers such as styrene, alphamethyl styrene, vinyl toluene, etc.; vinyl acetate; or other commonly available ethylenically unsaturated monomer compositions. Such monomers can be used in an amount of up to about 50 mol %, the balance being vinyl chloride. The primary requirement for the substantially thermoplastic polymeric material comprising vinyl chloride is that it retain sufficient thermoplastic properties to permit melt blending with wood fibre, permit formation of pellets, and to permit the composition material or pellet to be extruded or injection moulded in a thermoplastic process forming the rigid structural member. Polyvinyl chloride homopolymers and copolymers are available from a number of manufacturers. Preferred polyvinyl chloride materials are polyvinyl chloride homopolymer having a molecular weight of about 90,000 ± 50,000 most preferably about 85,000 ± 10,000.

Wood fibre

Wood fibre, in terms of abundance and suitability can be derived from either soft woods or evergreens or hard woods commonly known as broad leaf deciduous trees. Soft woods are generally preferred for fibre manufacture because the resulting fibres are longer, contain high percentages of lignin and lower percentages of hemicellulose than hard woods. While soft wood is the primary source of fibre for the invention, additional fibre make-up can be derived from a number of secondary sources including natural fibres including bamboo, rice, sugar cane, and recycled or reclaimed fibre from newspapers, boxes, computer printouts, etc.

However, the primary source for wood fibre of this invention comprises the wood fibre by-product of milling soft woods commonly known as sawdust or milling tailings. Such wood fibre has a regular reproducible shape and aspect ratio. The fibres are commonly at least 1 mm in l ngth, 0.3 mm in thickn ss and commonly have an aspect ratio of at least about 2 Preferably, the fibres are 1 to 7 mm in length, 0.3 to 1.5 mm in thickness with an aspect ratio betw en 2.5 and 9. The preferred fibre for use in this invention are fibres deriv d from

three processes common in the manufacture of windows and doors. First, wooden m mbers are commonly ripped or sawed to size in a cross grain direction to form appropriate lengths and widths of wood materials. The by-product of such sawing operations is a substantial quantity of sawdust. In shaping a regular shaped piece of wood into a useful milled shape, wood is commonly passed through a machine which selectively removes wood from the piece leaving the useful shape. Such milling operations produces substantial quantities of shaving sawdust or mill tailing by-products. Lastly, when shaped materials are cut to size and mitred joints, butt joints, overlapping joints, tail joints are manufactured from pre-shaped wooden members, substantial trim is produced. Such large trim pieces are commonly machined to convert the larger objects to wood fibre having dimensions approximating sawdust or mill tailing dimensions. These fibre sources can be mixed to form the fibre input, the streams can be pre-sized to sawdust dimensions or the mixed stream can be sized to desired particle size distributions.

Such sawdust material can contain substantial proportions of by-products including polyvinyl chloride or other polymer materials that have been used as coating, cladding or envelope on wooden members; recycled structural members made from thermoplastic materials; polymeric materials from coatings; adhesive components in the form of hot melt adhesives, solvent based adhesives, powdered adhesives, etc.; paints including water based paints, alkyd paints, epoxy paints, etc.; preservatives, anti-fungal agents, anti-bacterial agents, insecticides, etc., and other streams common in the manufacture of wooden doors and windows. The total by-product stream content of the wood fibre materials is commonly less than 25 wt % of the total wood fibre input into the polyvinyl chloride wood fibre product. Of the total recycle, approximately 10 wt % of that can compris a vinyl polymer commonly polyvinyl chloride. Commonly, the intentional recycle ranges from about 1 to about 25 wt %, preferably about 2 to about 20 wt %, most commonly from about 3 to about 15 wt %.

Moisture Control

Wood fibre, sawdust, has a substantial proportion of water associated with the fibre. Water naturally arises in the incorporation of natural materials in the growth cycle of living wood. Such water remains in the wood even after substantial drying cycles in lumber manufacture. In cured finished lumber used in the manufacture of wooden structural members, the sawdust derived from such operations after equilibration, can contain more than about 8% water. We have found that control of the water common in wood fibres used in the polyvinyl chloride and wood fibre composite materials and pellet products of the invention is a critical aspect to obtaining consistent high quality surface finish and dimensional stability of the PVC and wood fibre composite structural members. During the manufacture of the pellet material, it has been found that the removal of substantial proportion of the water is required to obtain a pellet optimized for further processing into the structural members. Trees when cut depending on relative humidity and season can contain from 30 to 300 wt % water based on fibre content. After rough cutting and finishing into sized lumber, seasoned wood can have a water content of from 20 to 30 wt % based on fibre content. Kiln dried sized lumber cut to length can have a water content typically in the range of 8 to 12%, commonly 8 to 10 wt % based on fibre. Some wood sources, such as poplar or aspen, can have increased moisture content while some hard woods can have reduced water content.

Because of the variation in water content of wood fibre source and the sensitivity of extrudate to water content control of water to a level of less than 8 wt % in the pellet based on pellet weight is important. Structural members extruded in non-vented extrusion process, the pellet should be as dry as possible and have a water content between 0.01 and 5%, preferably less than 3.5 wt %. When using vented equipment in manufacturing the extruded linear member, a water content of less than 8 wt % can be tolerated if processing conditions are such that vented extrusion equipment can dry the thermoplastic material prior to the final formation of the structural member of the extrusion head.

The maximum water content of the polyvinyl chloride/wood fibre composition or pellet will generally be 4 wt % or less, preferably 3.0 wt % or less, and most preferably the composition or pellet material contains from about 0.5 to 2.5 wt % water. Preferably, the water is removed after the material is mixed and formed into an extrusion prior to cutting into pellets. At this stage, water can be removed using the elevated temperature of the material at atmospheric pressure or at reduced pressure to facilitate water removal. The production can be optimized to result in substantial control and uniformity of water in the pellet product.

Composition and pellet manufacture

In the manufacture of the composition and pellet of th invention, the manufacture and procedure requires two important steps. A first blending step and a s cond pelletizing step.

During the blending step, the polymer and wood fibre are intimately mixed by high shear mixing components to form a polymer wood composite wh rein the polymer mixture comprises a continuous organic phase

and the wood fibre with the recycled materials forms a discontinuous phase suspended or dispersed throughout the polymer phase. The manufacture of the dispersed fibre phase within a continuous polymer phase requires substantial mechanical input. Such input can be achieved using a variety of mixing means including preferably extruder mechanisms wherein the materials are mixed under conditions of high shear until the appropriate degree of wetting and intimate contact is achieved. After the materials are fully mixed, the moisture content must be controlled at a moisture removal station. The heated composite is exposed to atmospheric pressure or reduced pressure at elevated temperature for a sufficient period of time to remove moisture resulting in a final moisture content of about 10, preferably 8 wt % or less. Lastly, the polymer fibre is aligned and extruded into a useful form.

The preferred equipment for mixing and extruding the composition and wood pellet of the invention is an industrial extruder device. Such extruders can be obtained from a variety of manufacturers, including Cincinnati Millicron.

The materials feed to the extruder can comprise from about 30 to 50 wt % of sawdust including recycled impurity along with from about 50 to 70 wt % of polyvinyl chloride polymer compositions. Preferably, about 35 to 45 wt % wood fibre or sawdust is combined with polyvinyl chloride homopolymer. The polyvinyl chloride feed is commonly in a small particulate size which can take the form of flake, pellet, powder, etc. Any polymer form can be used such that the polymer can be dry mixed with the sawdust to result in a substantially uniform premix. The wood fibre or sawdust input can be derived from a number of plant locations including the sawdust resulting from rip or cross grain sawing, milling of wood products or the intentional commuting or fibre manufacture from wood scrap. Such materials can be used directly from the operations resulting in the wood fibre by-product or the by-products can be blended to form a blended product. Further, any wood fibre material alone, or in combination with other wood fibre materials, can be blended with by-product from the manufacturer of wood windows as discussed above. The wood fibre or sawdust can be combined with other fibres and recycled in commonly available particulate handling equipment.

Polymer and wood fibre are then dry blended in appropriate proportions prior to introduction into blending equipment. Such blending steps can occur in separate powder handling equipment or the polymer fibre streams can be simultaneously introduced into the mixing station at appropriate feed ratios to ensure appropriate product composition.

In a preferred mode, the wood fibre is placed in a hopper volumetrically controlled to meter the sawdust at a desired volume while the polymer is introduced into a similar hopper have a volumetric metering input system. The volumes are adjusted to ensure that the composite material contains appropriate proportions on a weight basis of polymer and wood fibre. The fibres are introduced into a twin screw extrusion device. The extrusion device has a mixing section, a transport section and a melt section. Each section has a desired heat profile resulting in a useful product. The materials are introduced into the extruder at a rate of about 600 to 1000 pounds of material per hour and are initially heated to a temperature of about 220°C. In the feed section, the stage is maintained at about 215 to 225°C. In the mixing section, the temperature of the twin screw mixing stage is staged beginning at a temperature of about 220°C leading to a final temperature of about 200°C at spaced stages increasing in temperature at a rate of about 10°C per stage. One the material leaves the blending stage, it is introduced into an extruder portion wherein the mixed thermoplastic stream is divided into a number of cylindrical streams through a head section. Such head sections (about 15 to 20 cm (6 to 8 inches) in diameter) can contain from about 10 to 300, preferably 20 to 200 orifices having a cross-sectional shape leading to the production of a regular pellet. As the material is extruded from the head it is cut with a knife at a rotational speed of about 100 to 400 rpm resulting in the desired pellet length.

In similar fashion, the pellet materials of the invention are introduced into an extruder and extruded into the structural members of the invention. The extruder used is an extruder, as sold under the trade mark Moldovia 70, with twin parallel screws with an appropriately shaped four zone barrel and one oil heated zone. The equipment directs its product into a 1.3 m (4 foot) water tank at a rate of about 4 feet of structural member per minute. A vacuum gauge device can be used to maintain accurate dimensions in the extrudate. The melt temperature of the thermoplastic mass derived from the pellet shall be between 199 to 215°C (390 to 420°F). The melt in the extruder is vented to remove water and the vent is operated at a vacuum of not less than 7.6 cm (3 inches) of mercury. The extruder barrel has zones of temperature that decrease a maximum of about 240°C to a minimum of 180 to 190°C in eight successive steps.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIGURES 1 and 2 are cross-sectional drawings of structural members included in a window (Fig. 1) and a FWHD (Fig. 2).

Referring to the drawings, Fig. 1A shows cross-sectional drawings of the structural member components of a window unit of the invention. The window is placed in a wall structure form d from the jack stud 101 which

can have an installation flange 102 installed cooperating with the outside frame member 103. The outer fram member 103 can have a side style weather strip 126 that cooperates with the double hung window units fixed within the frame. The outer frame member 103 can have a thermoplastic jamb liner 104 as an outer envelope or cover. The double hung window unit can have high performance insulating glass 105, a vinyl glazing bead 106, a bottom rail sash 107, slidably mounted in the outer frame member 103. The sash bottom rail 107 can rest on a sill member 111 when closed. The exterior of the sill 111 can be trimmed using a stool trim 108 and a sill trim 110. Any of these structural members can be formed by extruding and injection moulding the PVC and wood fibre composite of the invention in an appropriate shape.

Further, Fig. 1B shows the upper portion of a window unit installed in an opening. The sash top rail 115 is slidably mounted in the head jamb 114 which also contains a screen channel 113 for mounting a screen 117. The sash contains insulating glass 125 that is commonly mounted in a side stile 119. The window also contains a side jamb 121 as the peripheral framing member of the window. In the double hung window unit (Fig. 1C), each sash meets at a joint area wherein the upper rail 122 meets the lower rail 124 with a weather strip 123 sealing the mounted between the rails. The upper and lower insulating glass 125 is shown.

Fig. 2 shows a typical wood sliding door cross-sectional drawing. The top of the door unit (Fig. 2B) is installed into a rough opening frame by the framing member 200. The top of the door is formed by the head jamb 201 which is mated with the top rail 203 which is fixed in place by the head stop and weather strip 202. The head jamb can also include a screen channel 204. The window also includes a side stile 205 and a side jamb 206. The centre joint (Fig. 2A) of the sliding glass door is formed as shown where the stationary stile 207 meets the operating stile 209 sealed by a weather strip 208. The window base (Fig. 2C) is framed by framing members 210 and 211. The door frame comprises an extruded aluminum screen track 221 covering an extruded c mposite sill 219. The bottom of the door is sealed with a weather strip 218. The window base rests on a subfloor 217 which is sealed by a finished floor 216. The bottom of the operating door 215 rests upon the composite member 219. Any of the structural members of the windows shown in the Figures can be made of the extruded thermoplastic polymer wood fibre composite of the invention.

Experimental

The following examples and data were developed to further illustrate the invention that is explained in detail above. The following information illustrates the typical production conditions and compositions and the tensil modulus of a structural member made from the pellet. The following examples and data shown in Table 1 contain a best mode.

EXAMPLE 1

A Cincinnati millicron extruder with an HP barrel, Cincinnati pelletizer screws, an AEGK-20 pelletizing head with 260 holes, each hole having a diameter of about 0.05 cm (0.02 inches) was used to make the pellet. The input to the pelletizer comprised approximately 60 wt % polymer and 40 wt % sawdust. The polymer material comprise a thermoplastic mixture of approximately 100 parts of polyvinyl chloride homopolymer, about 15 parts titanium dioxide, about 2 parts ethylene bis-stearamide wax lubricant, about 1.5 parts calcium stearate, about 7.5 Rohm & Haas 820-T acrylic resin impact modifier/process aid and about 2 parts of dimethyl tin thioglycolate. The sawdust comprises a wood fibre particle containing about 5 wt % recycled polyvinyl chloride having a composition substantially identical to that recited above. The initial melt temperature in the extruder was maintained between 350°C and 400°C. The pelletizer was operated at a vinyl sawdust combined through put of 363 kg (800 pounds) per hour. In the initial extruder feed zone, the barrel temperature was maintained between 215 to 225°C. In the intake zone, the barrel was maintained at 215 to 225°C, in the compression zone the temperature was maintained at between 205 to 215°C and in the melt zone the temperature was maintain d at 195 to 205°C. The die was divided into three zones, the first zone at 185 to 195°C, the second die zone at 185-195°C and in the final die zone at 195 to 205°C. The pelletizing head was operated at a setting providing 100 to 400 rpm resulting in a pellet with a diameter of 5 mm and a length as shown in the following Table.

Table I

PELLETIZER RESULTS

PVC/Wood Fiber	Pelletizer Melt TEMP, F	Pellet Length in.	Profile Melt Temp, F	Profile Visc.	Sawdust Moisture %	Pellet Moisture %	Pellet Bulk Density g/cc	Profile Density g/cc	Tensile Modulus psi
60/40		0.233	366 365	2580 2755	4.71, 4.83	0.96	.546 (.006)	1.426	990600
60/40		0.233	362	2452	4.71, 4.83	0.96	.546 (.006)		
70/30	375	0.080	375	2274	5.28	1.54	.454 (.007)	1.43	733300
70/30	375	0.080	376	2299	5.28	1.54	.454 (.007)	1.435	820100
50/50	372	0.084	382	2327	4.94	1.95	.347 (.002)	1.367	697600
70/30	374	0.195	385	2431		0.93	.595 (.005)	1.427	752900
70/30	374	0.195	378	2559		0.93	.595 (.005)	1.433	787600
60/40	375	0.089	377	1985	5.36	1.33	.418 (.003)	1.423	1103000
60/40	375	0.089	374	2699	5.36	1.33	.418 (.003)	1.408	815800
50/50	374	0.201	367	2541	5.33	2.09	.462 (.004)		
50/50	364	0.201	366	2670	5.33	2.09	.462 (.004)	1.397	724300
60/40	351	0.247	374	1948	4.62	1.03	.466 (.009)	1.426	860000
60/40	351	0.247	370	2326	4.62	1.03	.466 (.009)	1.433	996700
60/40	361	0.103	373	1605	5.53	1.57	.387 (.005)	1.431	985400
60/40	361	0.103	381	2221	5.53	1.57	.387 (.005)	1.435	855800
70/30	364	0.202	376	1837	5.25	1.50	.429 (.010)	1.433	868300
70/30	364	0.202	378	2376	5.25	1.50	.429 (.010)	1.434	798100
70/30	367	0.085	374	1593		1.48	.378 (.002)	1.438	744200
70/30	367	0.085	375	2145		1.48	.378 (.002)	1.439	765000
50/50	367	0.177	371	2393	5.08, 5.51	1.61	.434 (.007)	1.408	889200
50/50	367	0.177	371	3008	5.08, 5.51	1.61	.434 (.007)	1.528	1029000
50/50	366	0.085	370	2666		2.01	.438 (.003)	1.405	922100
50/50	366	0.085	369	2257		2.01	.438 (.003)	1.383	922600

In the Table, the composite material is made from a polyvinyl chloride known as GEON 427 obtained from B.F. Goodrich Company. The polymer is a polyvinyl chloride homopolymer containing about 88,000 ± 2,000. The wood fibre is sawdust by-product of milling soft woods in the manufacture of wood windows at Anders n Corporation, Bayport, Minnesota. The wood fibre input contained 5% intentional PVC impurity recycle. The modulus for the polyvinyl chloride compound m asured similarly to the composite materials is about 430,000 psi (2900 MPa). The Young's modulus is measured using an Instron Model 450S Series 9 software automated materials testing system and uses an ASTM method D-638. Specimens ar made according to the test and

are measured at 50% relative humidity, 23°C (73°F) with a cross head speed of 0.5 $cm.min^{-1}$ (0.2 $in.min^{-1}$).

After Table, it has been found that the preferred pellet of the invention displays a Youngs modulus of at least 500,000 psi (3400 MPa) and commonly falls in the range greater than about 800,000 psi (5500 MPa), preferably between 800,000 and 2.0 x 10^6 psi (5500 and 13800 MPa). Further, the coefficient of thermal expansion of the material is well matched to a compromising between aluminum, PVC and wood products and ranges from about 7.3 to 8.2 x 10^{-1} cm.°C (1.6 to 1.8 x 10^{-5} inch.°F^{-1}). It is believed that the superior properties of the structural members made from the composite or pellet of the invention are in large part due to the nature of the pellet set forth in the Table above. The Table clearly shows that the polyvinyl chloride and wood fibre can be combined at various proportions under a variety of temperature conditions to produce a regular pellet. The pellet then can be used in further extrusion processes to form a useful extruded structural member useful in the manufacture of environmentally sensitive windows and doors. The composite is a superior replacement for wood because it has similar mechanical properties but attains a dimensional stability and resistance to rot, and insect damage not attainable by wood products.

Table II

COMPOSITE SHRINKAGE RESULTS

PVC/Wood Fiber (wt-%) 0	Pelletizer Melt Temp, °F	Pellet Length in.	mm	Profile Melt Temp, F	Profile Melt Pressure (psi)	Member Tensile Modulus (psi)	190°F Water Bath Shrinkage	180°F Oven Shrinkage
60/40		.233		366.5 365.8	2580 2755	990600	0.17%	0.16%
60/40		.233		362.5	2452			
70/30	375.7 (1.5)	.080		373.5	2274	733300	0.18%	0.34%
70/30	375.7 (1.5)	.080		376.8	2299	820100	0.14%	0.32%
50/50	372.5 (1.9)	.084		382.8	2327	697600	0.00%	0.29%
70/30	374.8 (1.5)	.195		385	2431	762900	0.06%	0.31%
70/30	374.8 (1.5)	.195		378.9	2559	787600	0.00%	0.27%
60/40	375.9 (1.1)	.089		377.1	1985	1103000	0.00%	0.22%
60/40	375.9 (1.1)	.089		374.6	2899	815800	0.20%	0.05%
50/50	374.2 (.9)	.201		367.6	2541			
50/50	364.2 (.9)	.201		366.4	2670	724300		
60/40	351.8 (4.9)	.247		374.7	1948	860000	0.00%	0.25%
60/40	351.8 (4.9)	.247		370.5	2326	998700	0.04%	0.20%
60/40	361.2 (1.3)	.103		373.4	1605	985400	0.00%	0.23%
60/40	361.2 (1.3)	.103		381.5	2221	855800	0.07%	0.21%
70/30	365.8 (1.6)	.202		376.5	1837	868300	0.05%	0.26%
70/30	364.8 (1.6)	.202		378.1	2376	788100	0.17%	0.22%
70/30	367.5 (1.1)	.085		374.9	1593	744200	0.20%	0.34%
70/30	367.5 (1.1)	.085		375.2	2145	765000		
50/50	367.4 (1.7)	.177		371.9	2393	899200		
50/50	367.4 (1.7)	.177		371.2	3008	1029000	0.00%	0.21%
50/50	366.4 (2.6)	.085		370.7	2666	922100	0.05%	0.23%
50/50	366.4 (2.6)	.085		369.6	2257	922600	0.09%	0.24%
100*						429300	0.95%	0.85%

*PVC

The data in Table II shows the production of a composite structural member from a composite pellet. The member has excellent tensile modulus and high temperature shrinkage properties.

Pellets of the invention were formed into standard test units using a standard injection moulding apparatus. The results are shown in the following Table. The test production run and conditions follow.

Table III

Injection Moulded Samples		
DESCRIPTION	TENSILE MODULUS (ksi)	STANDARD DEVIATION (ksi)
High melt/large pellet/40%	1205	242.4
PVC	488.8	28.4
High melt/small pellet/40%	1232	133.3

These data also demonstrates the injection mouldability of composite materials.

Pellet	Small 1 Lg. Pellet 40%	Large 1 Lg. Pellet 40%	Small 2 PVC	Large 2 PVC	Small 3 Sm. Pellet 40%	Large 3 Sm. Pellet 40%	
STD. CYCLE:	30.0	30.0	30.0 sec.	30.0 sec.	30.0 sec.	30.0 sec.	
Inj. Fast Time	---	---	---	---	---	---	
Inj. Boost Time	2.5	3.0	2.5	3.0	3.0	3.0	
Fill Time	1.0 to 1.2	1.2 to 1.5	1.2	1.6	1.2	1.6	
Inj. Mold Time	12.0	12.0	12.0	12.0	12.0	12.0	
Mold Closed Time	25.0	25.0	25.0	25.0	25.0	25.0	
Mold Open Time	0.5	0.5	0.5	0.5	0.5	0.5	
Inj. Fast Pressure	---	---	---	---	---	---	
Inj. Boost Pressures	1800 psi	1850 psi	1300 psi	1350 psi	1600 psi	1700 psi	
Inj. Mold Pressure	800 psi	800 psi	1000 psi	1000 psi	1000 psi	1000 psi	
Back Pressure	30 lbs.	30 lbs.	30 lbs.	30 lbs.	30 lbs.	30 lbs.	
Inj. Speed	w/o Fast	w/o Fast	w/o Fast	w/o Fast	w/o Fast	w/o Fast	
Screw Speed	Slow	Slow	Slow	Slow	Slow	Slow	
Feed	1 1/2"	2"	1 1/2"	2"	1 1/2"	2"	
Cushion	1/2"	1/2"	1/2"	1/2"	1/2"	1/2"	
Decompress	Off	Off	Off	Off	Off	Off	
Front Zone	340°F	340°F	340°F	340°F	340°F	340°F	
Rear Zone	330	330	330	330	330	330	
Melt Temp.	360 to 370	360 to 370	360 to 370	360 to 370	360 to 370	360 to 370	
Nozzle Radius	1/2"						
Nozzle Orifice	Same as Mold						
Core Seq.	None	---	---	---	---	---	
E. J. Stroke	Max.	---	---	---	---	---	
K. O. Bar Length	The Backs Std.	---	---	---	---	---	
K. O. Stud Length	5/8"	---	---	---	---	---	
Mold Open Stroke	16"	---	---	---	---	---	
Multi Stroke	2	---	---	---	---	---	
Die Slow	To Fast - Med.	---	---	---	---	---	
A-Side Water	Tower	Tower	Tower	Tower	Tower	Tower	Tower Water
B-Side Water	Tower	Tower	Tower	Tower	Tower	Tower	Average 76°
Pot Settings							
Full Open	Auto	Auto	Auto	Auto	Auto	Auto	

The materials of the invention were further tested for fungal stability. The results are shown in Table IV.

Table IV

ASTM D-1413 (Fungal Resistance Test) Results

PVC Composite:

Use	PVC Wt-%	Fungi	Wt. After Leaching (g)	Final Wt. (g)	Wt. Loss (g)	Wt. Loss (%)
Soil Block*		GT	8.56	8.56	0.00	0.00%
Soil Block		GT	8.64	8.64	0.00	0.00%
Soil Block		GT	8.47	8.45	0.02	0.24%
Soil Block		GT	8.58	8.58	0.00	0.00%
Soil Block		GT	8.57	8.57	0.00	0.00%

(Average = 0.05%
S.D. = 0.11%)

Use	PVC Wt-%	Fungi	Wt. After Leaching (g)	Final Wt. (g)	Wt. Loss (g)	Wt. Loss (%)
Soil Block		TV	9.23	9.23	0.00	0.00%
Soil Block		TV	8.51	8.48	0.03	0.35%
Soil Block		TV	8.93	8.93	0.00	0.00%
Soil Block		TV	8.94	8.94	0.00	0.00%
Soil Block		TV	8.35	8.35	0.00	0.00%

(Average = 0.07%
S.D. = 0.16%)

Untreated Ponderosa Pine Controls:

Use	Fungi	Initial Wt. (g)	Final Wt. (g)	Wt. Loss (g)	Wt. Loss (%)
Soil Block	GT	3.07	1.41	1.66	54.07%
Soil Block	GT	3.28	1.59	1.69	51.52%
Soil Block	GT	3.42	1.65	1.77	51.75%
Soil Block	GT	3.04	1.29	1.75	57.57%
Soil Block	GT	3.16	1.71	1.45	45.89%

(Average = 52.16%
S.D. = 4.27%)

Table IV (continued)

Use	Fungi	Initial Wt. (g)	Final Wt. (g)	Wt. Loss (g)	Wt. Loss (%)
Soil Block	TV	3.15	2.88	0.27	8.57%
Soil Block	TV	3.11	2.37	0.74	23.79%
Soil Block	TV	3.02	2.73	0.29	9.60%
Soil Block	TV	3.16	2.17	0.45	14.24%
Soil Block	TV	3.06	2.41	0.65	21.24%

(Average = 15.49%; S.D. = 6.82%)

Treated Ponderosa Pine Controls:

Use	PVC Wt-%	Fungi	Wt. After Leaching (g)	Final Wt. (g)	Wt. Loss (g)	Wt. Loss (%)
Soil Block		GT	3.53	3.49	0.04	1.13%
Soil Block		GT	3.37	3.35	0.02	0.59%
Soil Block		GT	3.60	3.59	0.01	0.28%
Soil Block		GT	3.28	3.25	0.03	0.91%
Soil Block		GT	3.41	3.38	0.03	0.88%
			(Average = 0.76% S.D. = 0.33%)			
Soil Block		TV	3.41	3.40	0.01	0.29%
Soil Block		TV	3.80	3.78	0.02	0.53%
Soil Block		TV	3.37	3.35	0.02	0.59%
Soil Block		TV	3.39	3.36	0.03	0.88%
Soil Block		TV	3.35	3.33	0.02	0.60%
			(Average = 0.58% S.D. = 0.21%)			

GT = Gloeophyllum Trabeum (brown-rot fungus)
TV = Trametes versicolor (white-rot fungus)

* A cube as defined in ASTM D-1413

The composite materials were superior to the pine samples.

Tensile modulus is defined as the steepest linear region of the stress/strain (based on original sample dimensions) curve between the origin and material yield (Instron series IX calculation 19.3). Tensile yield is the first stress level at which the stress/strain curve attains a zero slope (calculation 8.4). Toughness is the integrated area under the load/displacement curve divided by the volume of the sample gauge length (calculation 43.5).

PRODUCTS TESTED

1) Secondary PVC 0.25 cm thick extruded strip
2) 60/40 Nonp lletized 0.25 cm thick extruded strip
3) 60/40 Pelletized 0.25 cm thick extruded strip

4) 60/40 Pelletized with Additive 0.25 cm thick extruded strip
5) Treated Ponderosa Pine

Purpose

To determine the water absorption characteristics of the above specimens.

Conclusion

Secondary PVC showed the lowest and most consistent results in change in weight over twenty-two hours. Ponderosa Pine demonstrated the highest change and variability in weight change over twenty-two hours. All three of the 60/40 blends performed similarly absorbing less than 10% as much water as treated pine.

The Secondary PVC, however, in volume change over twenty-two hours, had the highest change. Again, the three 60/40 blends were approximately the equal. Ponderosa pine performed about four times worse than the blends (see data below).

PRODUCT	AVERAGE % WEIGHT CHANGE AFTER 22 HOURS	AVERAGE % WEIGHT CHANGE AFTER 22 HOURS
1	0.45 (0.34)	20 (4.0)
2	5.4 (0.88)	3.4 (3.7)
3	4.3 (0.95)	3.7 (3.0)
4	3.5 (0.56)	3.6 (2.7)
Ponderosa pine	71 (22)	12 (6.9)

Method of Testing:

Ponderosa pine samples were made by cutting 0.25 cm thick strips from the inside stop portion of head/sill profiles. Wood moisture content at the time of water soak testing was determined to be 14% using the ov n dry procedure of ASTM D-143.

Water absorption samples were made by cutting disks with a diameter of approximately 2.74 cm (1.080 in) from the pine and extruded samples. More samples (15) were prepared from the Ponderosa Pine because of its obvious variability in water absorption characteristics. This allowed for a better chance of more consistent data readings. Only six samples were prepared from of the other materials.

Testing procedures and calculations followed ASTM D1037 specifications.

Features of polymer/wood composite materials, and components and members made from such materials, are disclosed in US patent applications numbers 07/938604, 07/938364 and 07/938365, and the European patent applications which claim priority from those applications which are being filed with this application. Reference is to be made to the specifications of those applications for information regarding those features.

Table V

H_2O Adsorption and Thickness Swelling

Samples	Initial	22 Hrs.	Weight Change	% Weight Change	Initial	22 Hrs.	Volume Change	% Volume Change
SECONDARY PVC								
1	2.2572	2.2703	0.0131	0.58	0.125	0.098	0.027	21.5
2	2.206	2.2163	0.0103	0.47	0.128	0.105	0.023	18
3	2.2064	2.208	0.0016	0.07	0.123	0.091	0.032	26
4	2.1879	2.1895	0.0016	0.07	0.088	0.106	0.018	20.5
5	2.3189	2.3412	0.0223	0.96	0.094	0.111	0.017	18.1
6	2.2525	2.2646	0.0121	0.54	0.106	0.12	0.014	13.2
			Avg.	0.45(.34)			Avg.	20(04)
60/40 NON-PELLETIZED								
1	1.5637	1.6444	0.0807	5.2	0.072	0.074	0.002	2.8
2	1.5033	1.5868	0.0835	5.6	0.076	0.077	0.001	1.3
3	1.5984	1.6694	0.071	4.4	0.078	0.08	0.002	2.6
4	1.5191	1.5872	0.0681	4.5	0.074	0.073	0.001	1.4
5	1.4515	1.5462	0.0947	6.5	0.074	0.075	0.001	1.4
6	1.5099	1.5948	0.0939	6.3	0.074	0.082	0.008	10.8
			Avg.	5.4 (.88)			Avg.	3.4(3.7)
60/40 PELLETIZED								
1	1.6321	1.7074	0.0753	4.6	0.084	0.077	0.007	8.3
2	1.6262	1.7006	0.0804	4.9	0.078	0.083	0.005	6.4
3	1.5855	1.6735	0.088	5.6	0.076	0.075	0.001	1.3
4	1.6814	1.7311	0.0497	3	0.083	0.082	0.001	1.2
5	1.6851	1.7486	0.0635	3.8	0.084	0.082	0.002	2.4
6	1.6682	1.7284	0.0602	3.6	0.079	0.081	0.002	2.5
			Avg.	4.3(.95)			Avg.	3.7(3.0)

Table V (continued)

Samples	Initial	22 Hrs.	Weight Change	% Weight Change	Initial	22 Hrs.	Volume Change	% Volume Change
PONDEROSA PINE								
1	0.6747	1.0531	0.3784	56	0.107	0.084	0.023	21
2	0.673	1.0401	0.3671	55	0.069	0.082	0.013	19
3	0.6659	1.0322	0.3763	57	0.075	0.078	0.003	4
4	0.4836	0.8846	0.401	83	0.077	0.079	0.002	2.6
5	0.4654	0.8527	0.3963	85	0.073	0.074	0.007	9.6
6	0.6504	1.0438	0.3934	60	0.071	0.083	0.012	16.9
7						0.081	0.004	
8	0.749	1.244	0.4954	66	0.081	0.088	0.007	5.2
9	0.4763	1.0667	0.5904	24	0.072	0.08	0.009	12.5
10	0.4817	0.8357	0.374	81	0.071	0.074	0.003	4.2
11	0.6574	0.8795	0.2221	34	0.076	0.089	0.013	17.1
12	0.4685	0.8981	0.4296	92	0.071	0.082	0.011	15.5
13	0.8917	1.1006	0.4089	59	0.07	0.08	0.01	14.3
14	0.6605	1.0323	0.3718	56	0.101	0.08	0.021	20.8
15	0.4817	0.8695	0.3879	81	0.073	0.075	0.002	2.7
			Avg.	71(22)			Avg.	12(6.9)

Claims

1. A polymer wood composite structural member, suitable for use as a replac ment for a wood structural member, which has a modulus of greater than 5 x 10^5 psi (3440 MPa), and a co fficient of thermal x-pansion less than 3 x 10^{-5} in/in-°F (5.4 x 10^{-5} °C^{-1}), and which comprises a blend of wood fibre and a

polymer comprising vinyl chloride, in which the amount of wood fibre is at least about 30% and the amount of the polymer is at least about 30%, the amounts being expressed by weight as a proportion of the total weight of the wood fibre and the polymer.

2. A composite structural member as claimed in claim 1, in which the coefficient of thermal expansion is less than about 2.5×10^{-5} in/in-°F (4.5×10^{-5} °C^{-1}).

3. A composite structural member as claimed in claim 1 or claim 2, in which the coefficient of thermal expansion is at least about 1.5×10^{-5} in/in-°F (2.7×10^{-5} °C^{-1}).

4. A composite member as claimed in any one of claims 1 to 3, in which the modulus is greater than 7.5×10^5 psi (5171 Mpa).

5. A composite member as claimed in any one of claims 1 to 4, which has a rectangular cross-section with a width greater than about 1 cm and a depth than about 1 cm

6. A composite member as claimed in any one of claims 1 to 4, which has a square cross-section with a width greater than about 1 cm.

7. A composite member as claimed in any one of claims 1 to 6, which has a length greater than about 30 cm.

8. A composite member as claimed in any one of claims 1 to 7, in which the amount of the polymer in the blend is more than about 35%, more preferably more than about 50%.

9. A composite member as claimed in any one of claims 1 to 8, in which the amount of the wood fibre in the blend is more than about 35%.

10. A composite member as claimed in any one of claims 1 to 9, in which the amount of polymer in the blend is less than about 70%, preferably less than about 65%.

11. A composite member as claimed in any one of claims 1 to 7, in which the blend comprises about 35 to about 65% of the polymer and about 35 to about 55% of wood fibre.

12. A composite member as claimed in any one of claims 1 to 7, in which the blend comprises about 50 to about 70% of the polymer and about 30 to about 50% of wood fibre.

13. A composite member as claimed in any one of claims 1 to 12, which has a shaped member cross-section.

14. A composite member as claimed in any one of claims 1 to 13, which has been formed by extrusion.

15. A composite member as claimed in claim any one of claims 1 to 14, which comprises one or more of (a) jamb, (b) a stop, (c) a rail, (d) a casing, (e) a sill, (f) a stile, (g) a grill component, or (h) a track.

16. A composite member as claimed in claim 14, which comprises a window sash track or a door track.

FIG. 1A

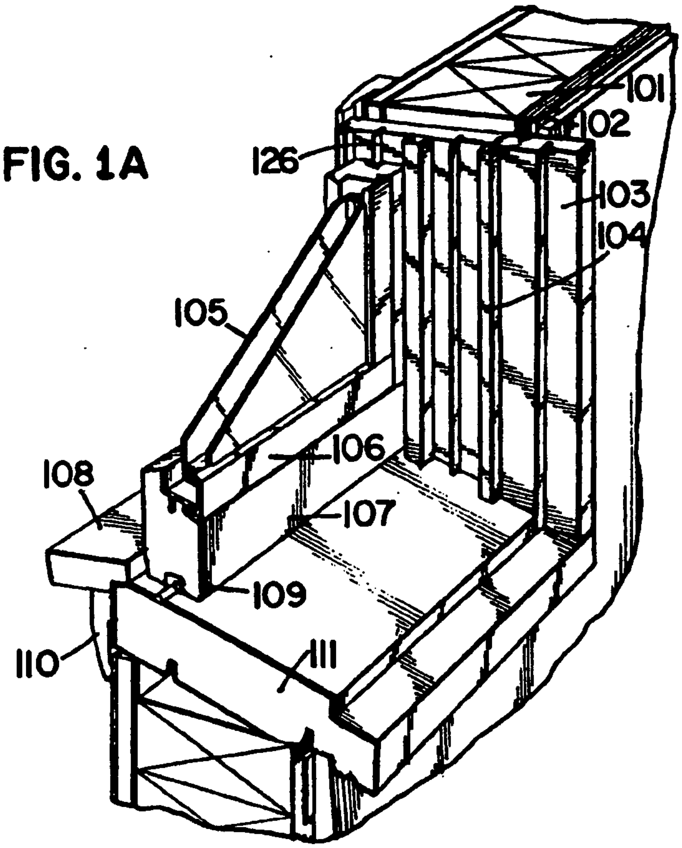
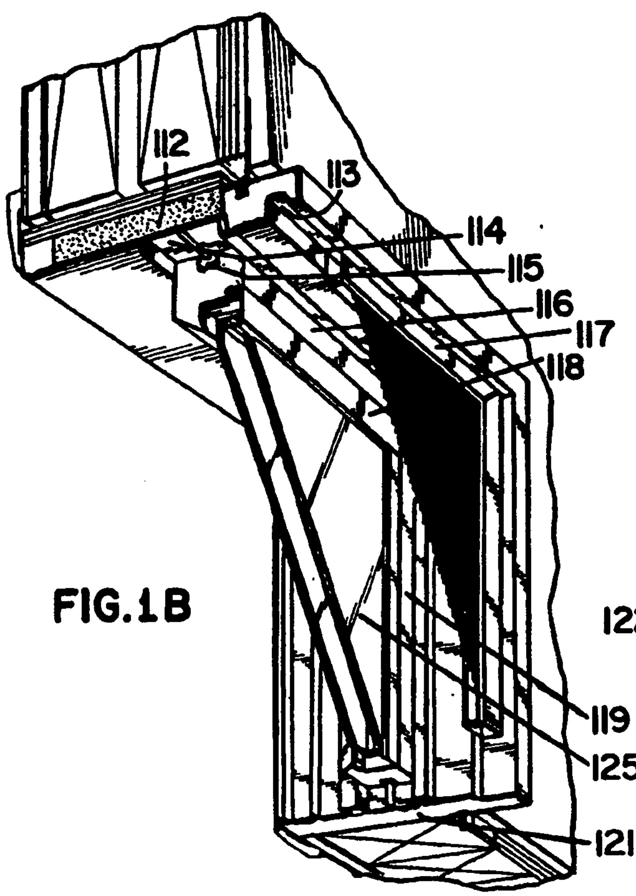


FIG.1B



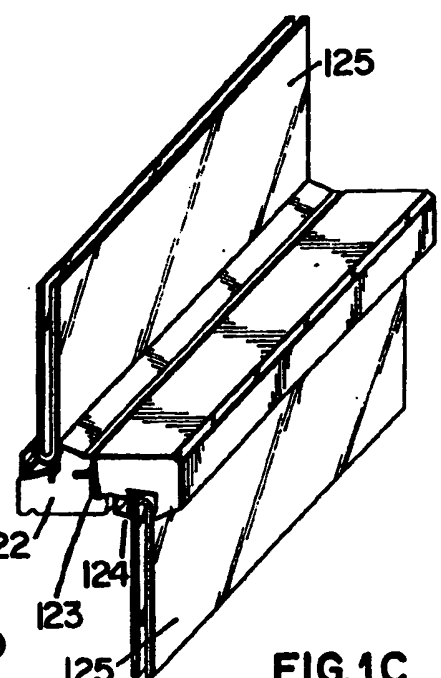


FIG.1C

FIG. 2A

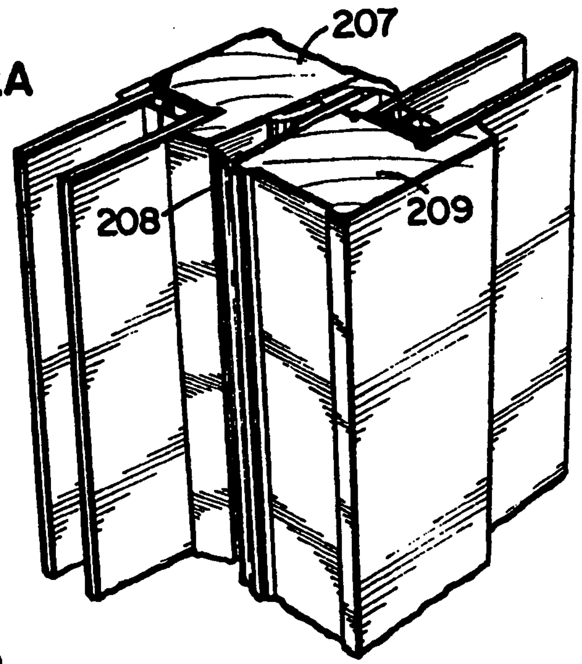
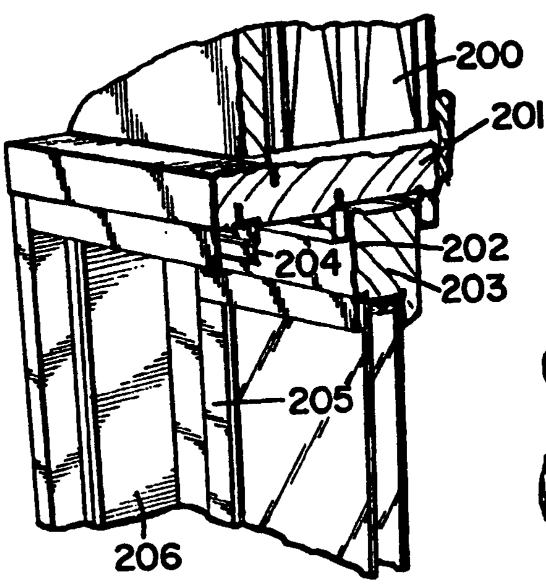


FIG. 2B



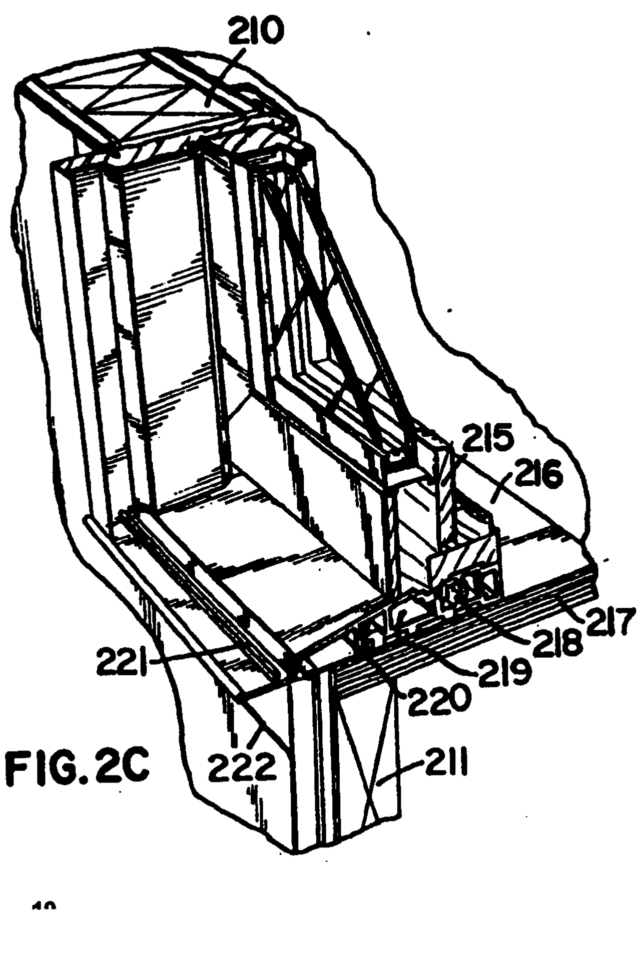


FIG. 2C

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 6843

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	FR-A-2 344 101 (REHAU PLASTIKS) * page 3, line 7 - line 35 * ---	1-16	B27N3/28 B29C67/16 E06B3/00 //B29K27:06
A	FR-A-2 564 374 (GREPP) * page 1, line 16 - line 25 * * page 3, line 33 - line 36; table * ---	1-16	
A	DATABASE WPI Week 8442, Derwent Publications Ltd., London, GB; AN 84-259377 & JP-A-59 156 712 (AIN ENG.) 6 September 1984 * abstract * ---	1-16	
A	US-A-3 956 541 (PRINGLE) * column 4, line 25 - line 27; claim 1 * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			B27N B29C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 November 1993	ATTALLA, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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